

# Surface Area of The Q400 Aircraft Based On Google SketchUp Pro Software

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## Objective

As proposed by Dr. Arnold R. Miller [1], the purpose of this study is to determine the surface area of the entire Bombardier Q400 airplane, as well as the surface area of the fuselage only, using an accurate 3D (three-dimensional) computer model that corresponds to the dimensions of the actual airplane. Specifically, the ratio of these surface areas will be determined. The 3D model was measured with Google SketchUp Pro [2] software, a 3D modeling program released by @Last Software in 2000.

## History

Before proceeding with work in Google SketchUp, Josh Reilly searched online for 3D models of the Q400. A model was first obtained from FormFonts, an online collection of various 3D graphics and models. Dr. Arnold Miller and Mr. Reilly spent time "cleaning up" (removing nonessential geometric shapes) and "patching" (filling in holes with a surface) the model. The accuracy of the model was examined by determining, using the parallel projection view in SketchUp, the ratio of the frontal areas (fuselage to entire airplane). This ratio was found to be 0.27, a number significantly higher than the value originally calculated by two independent methods (see "Frontal Areas of the Q400 Airplane Based on ImageJ Software" [3]). This implied inaccuracy in the CAD model.

Dr. Miller requested that Kristen Johnson, contract employee of Vehicle Projects, complete an analysis that compared the various dimensions of the model provided by Bombardier with those of the FormFonts model. The final analysis showed the dimensions of the models to be significantly different, particularly the fuselage (frontal area and width), wing area and thickness, and tail area.

Due to these inaccuracies, the FormFonts model was discarded and a second Q400 model was purchased for \$150 from TurboSquid [4], an online catalog of over 200,000 3D models. This model was similarly analyzed by Ms. Johnson, utilizing ImageJ software to compare the dimensions of the Bombardier images to the TurboSquid model. The second model proved to be much more accurate, but the fuselage was still too large, while the tail connection was too narrow.

A third, and final model (entitled "Bombardier Q400 Generic White" by author BlueGreen, Product ID 528468), was purchased for \$325 from TurboSquid after the author verified the model was accurately drawn to scale, compared with the dimensions published on the Bombardier Q400 Fact Sheet [5]. (The \$150 purchase price of the initial TurboSquid model was credited toward the \$325 price.) The original Q400 3D model was obtained from TurboSquid in 3DS file format (Autodesk 3DS Max), and was converted by TurboSquid into an SKP (native

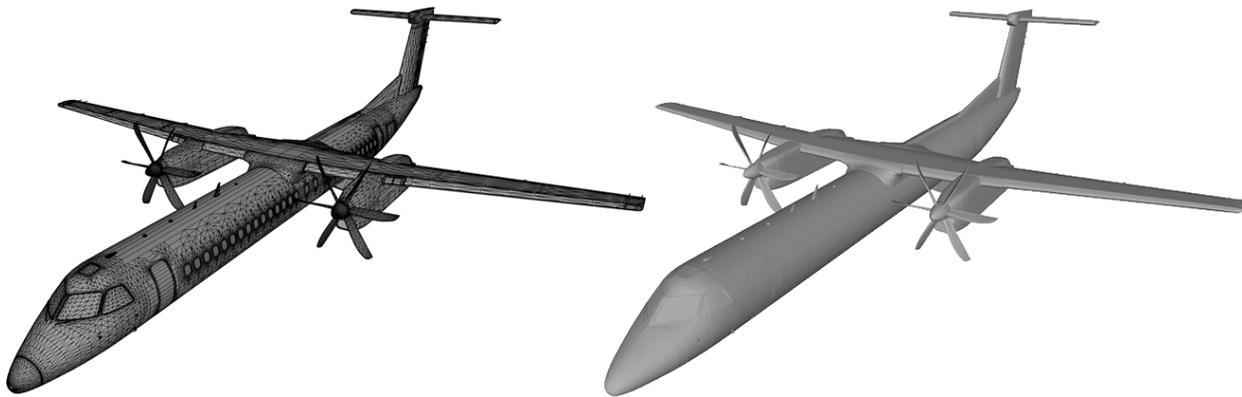
Google SketchUp format) file. This file was then independently analyzed by Ms. Johnson, and was found to be the most accurate model yet.

### Method of Measurement

To verify the accuracy of the surface area function tool in Google SketchUp, Mr. Reilly created a cube with known measurements of 1 meter in length, width, and height. He then selected the entire cube and chose option "Area" of "Selection," which accurately produced the value of 6 m<sup>2</sup>. With the surface area tool tested, Mr. Reilly proceeded to measure the Q400 model.

Mr. Reilly used the *Tape Measure Tool* in SketchUp to match the known fuselage maximum diameter of the Q400 airplane, while preserving the original ratio of all dimensions. First, to set up the correct units of measurement for the SketchUp model, *Window > Model Info > Units* is selected, and the desired unit, "meters," is chosen. The *Format: Decimal* option is then chosen to select the accuracy of measurement; in this case, each area was measured to six decimal places. Using the fuselage maximum diameter of 2.7 m as the base scaling measurement, the *Line Tool* was utilized to draw a line across the center of the fuselage. Mr. Reilly then clicked the endpoints of the line with the *Tape Measure Tool* and entered "2.7 m" as the dimension. SketchUp then resized the model, utilizing the fuselage maximum diameter as its scale.

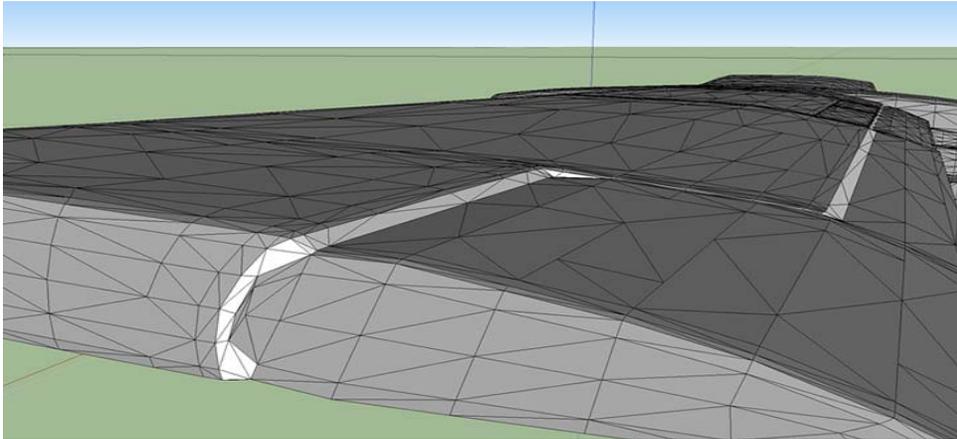
Extensive simplification of the 3D model was required, since it was highly detailed and contained extraneous geometry (geometry that was unrelated to the exterior surface of the plane) that would prevent accurate determination of surface area. An exterior shell, or single monolithic surface, was thus created to represent the surface area of the physical Q400 airplane by removing



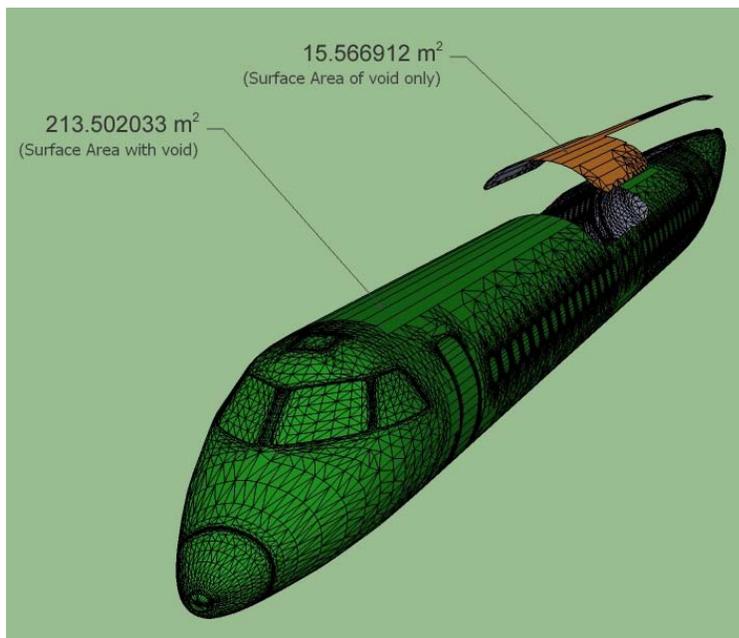
**Figure 1.** On the left, the Q400 airplane with all geometry showing. On the right, the exterior shell of the Q400, with edges turned off.

all extraneous geometry (see Fig. 1). Geometry was removed utilizing the *Eraser Tool*, while the *Line Tool* was used to create surfaces to fill in small gaps in the model (see Fig. 2). These gaps were found around all movable components of the airplane, such as the wings, as well as the windshield, doors, windows, etc. Finally, the *Intersect Faces > With Selection* operation was

used to join (i.e., create intersections of surfaces that previously passed through one another) adjacent parts of the model.



**Figure 2.** An example of patching a gap found on the surface area of the wing.



**Figure 3.** On the left, the Q400 airplane with wings and tail removed, and measurements showing the surface areas of the fuselage-with-void ( $S_f$ ) and spatula-like void ( $S_{\text{hole}}$ ), respectively.

## Results

To determine the desired ratio, we made two measurements: (a) the surface area of the complete, enclosed fuselage and (b) the surface area of the entire airplane.

(a) Fuselage: In order to determine the surface area of the fuselage only, wings and tail were removed, leaving behind a spatula-like hole (or void) (see Fig. 3). The hole was then patched to create a complete, enclosed fuselage. We denote the surface area of the fuselage-with-hole as  $S_f$  and the area of the spatula-shaped patch as  $S_{\text{hole}}$ . The sum of these areas,  $S_f + S_{\text{hole}}$ , gives the area of the complete, enclosed fuselage. We measured  $S_f = 213.502033 \text{ m}^2$  and  $S_{\text{hole}} = 15.566912 \text{ m}^2$  (see Fig. 3).

(b) Complete airplane: In finding the surface area of the entire Q400 airplane, three specific cases were measured:

(i) without propeller blades and without the stems but with surfaces covering the hole where the stems had resided, while keeping the curvature of the overall spinner consistent (denoted  $SA_1$ ); measured value  $SA_1 = 481.775826 \text{ m}^2$  (see Fig. 4).

(ii) without propeller blades but with the stems in place (denoted  $SA_2$ ); measured value  $SA_2 = 481.844248 \text{ m}^2$  (see Fig. 5).

(iii) with propeller blades (denoted  $SA_3$ ); measured value  $SA_3 = 499.235712 \text{ m}^2$  (see Fig. 4).

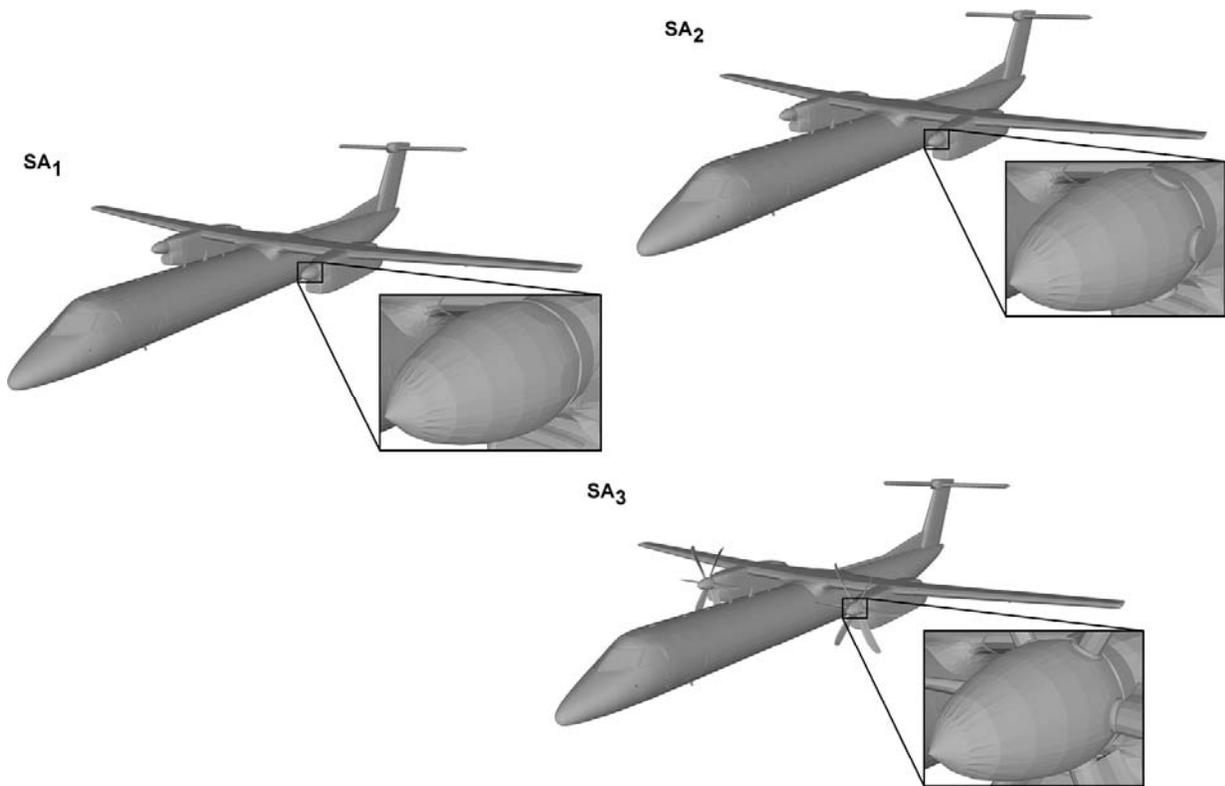
## Conclusions

Because there were three different ways of measuring the entire airplane surface area, there are three different ratios of surface areas. We illustrate the desired number for one of the cases:

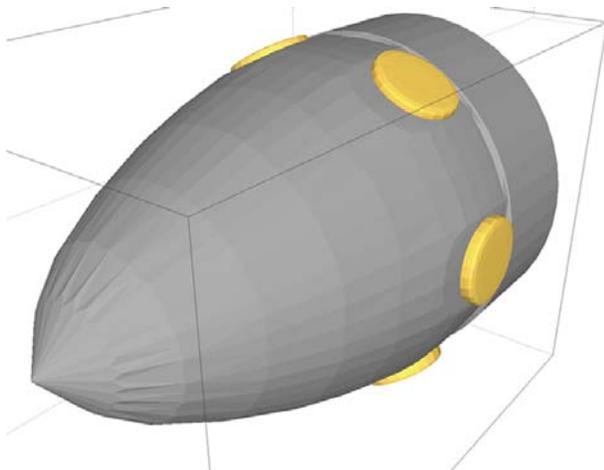
$$\text{Ratio 1} = (S_f + S_{\text{hole}})/SA_1 = (213.502 + 15.567)/481.776 = 229.069/481.776 = 0.4755$$

## References

- [1] Miller, A. Vehicle Projects LLC, phone call with Joshua R. Reilly, 12 September 2011.
- [2] Google SketchUp Pro, Version 8. Website: <http://sketchup.google.com>
- [3] Johnson, K. "Frontal Areas of the Q400 Airplane Based on ImageJ Software," 15 July 2011.
- [4] TurboSquid. Website: <http://turbosquid.com>
- [5] Bombardier Q400 Fact Sheet. Website: [http://q400nextgen.com/en/medias/gallery/literature/factsheetq400\\_en.pdf](http://q400nextgen.com/en/medias/gallery/literature/factsheetq400_en.pdf)

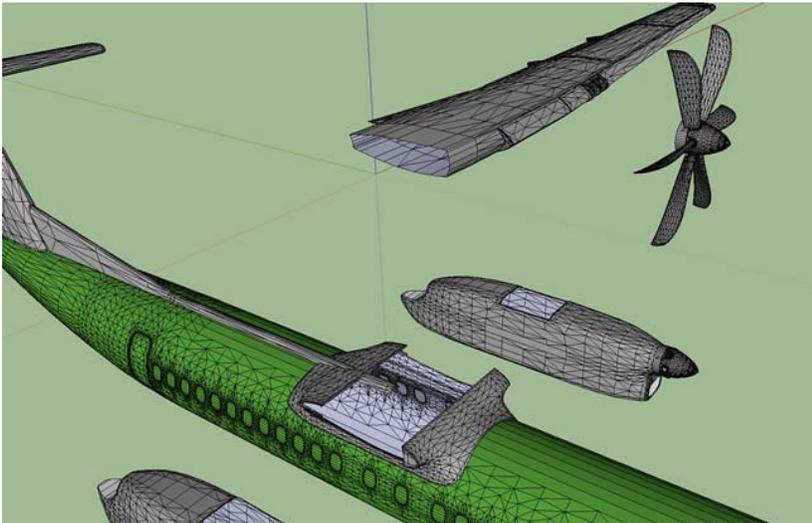


**Figure 4.** Drawings showing characteristic differences in areas SA<sub>1</sub>, SA<sub>2</sub>, and SA<sub>3</sub>.

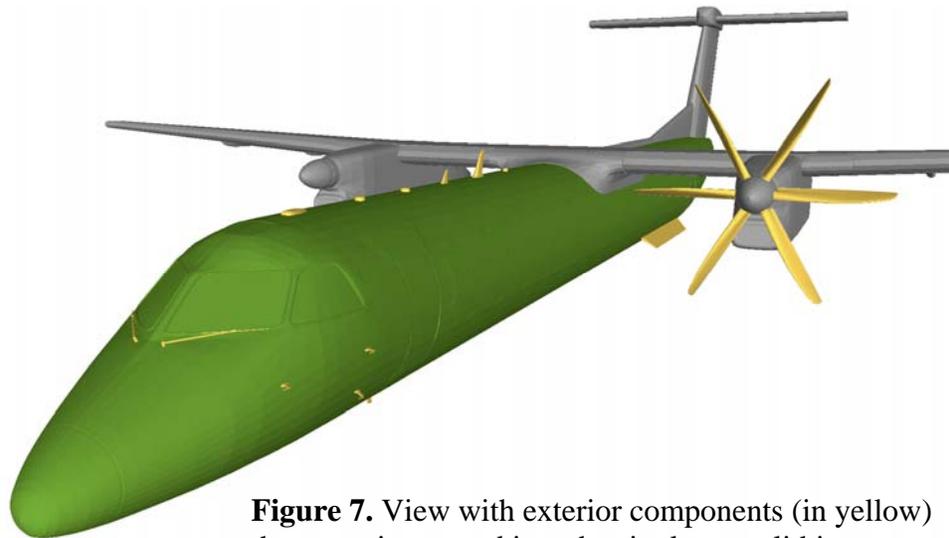


**Figure 5.** An illustration of the blades removed from the spinner with the blade stems (yellow) remaining, and the gaps around the stems patched.

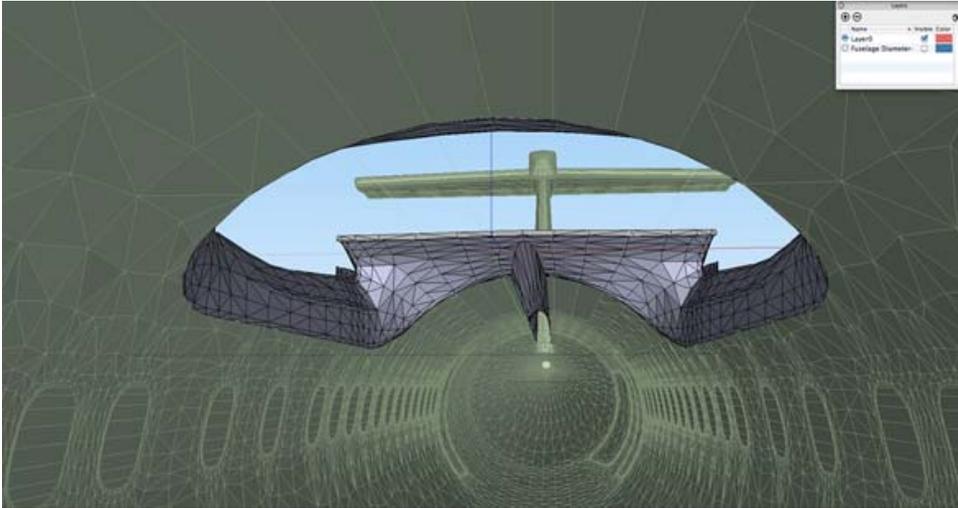
## Appendix



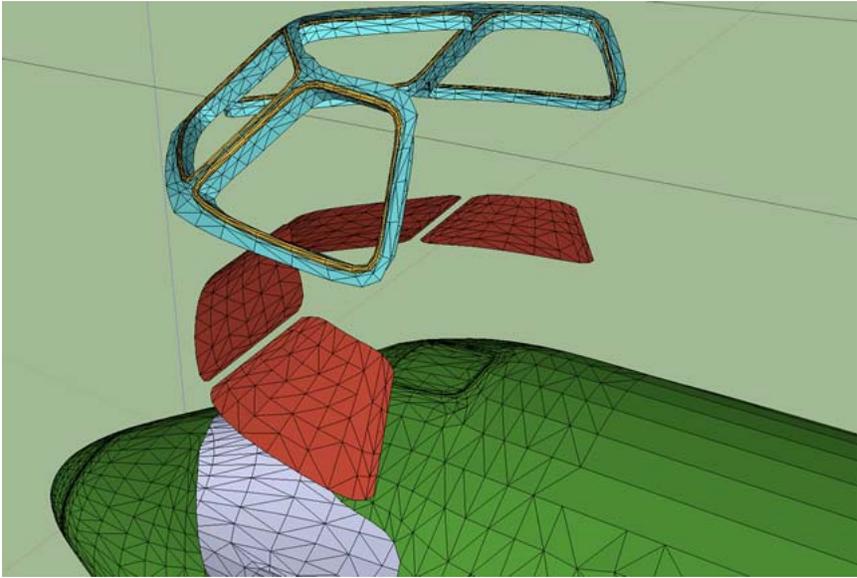
**Figure 6.** Exploded view, showing the hollow interior of some of the Q400 airplane components during the simplification process.



**Figure 7.** View with exterior components (in yellow) that were integrated into the single monolithic surface.



**Figure 8.** View from within the fuselage, looking toward tail section, showing the geometry connecting the wings to the fuselage.



**Figure 9.** Exploded view, showing process of separating components in the windshield area before intersecting and removing extraneous geometry.